Regression Modeling to Enhance Spatial Representations of Fuel Loads and Fire Hazards

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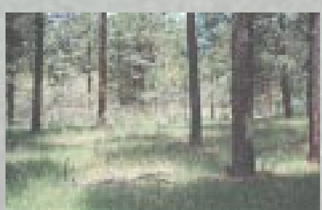
Abstract

To develop more robust databases for wildfire behavior modeling and for wildfire hazard assessment, we examined the spatial and topographic relationships of fuels in forest communities of the Los Alamos region. To accomplish this, we sampled plant communities over a three-year period. The data were summarized and analyzed using linear modeling techniques. From these analyses, it was found that both overstory and understory fuels were related to linear and quadratic functions of topographic and remotely sensed variables. As examples, the final regression models for percent canopy cover (F = 16.23, P-value <0.0001, R-square of 0.571) and for trees per acre less than 8 inches DBH (F = 15.74, P-value <0.0001, R-square of 0.651) were both significant. These and similar models of other variables are being used to predict fuel levels and fire hazards at unsampled locations throughout the study area.

Introduction

Land managers of the Los Alamos region are reducing fire hazards in forests by thinning overstory tree densities and removing ground fuels and ladder fuels. This can be done in a more efficient and cost-effective manner if we know the spatial and topographic distributions of these fuels (Balice et al., 2000a). Presently, we estimate fuel loads across the landscape by categorizing previously established data layers, such as land cover (Balice et al., 1997; Balice 1998). Frequently we employ remote sensing techniques for this purpose (Koch et al., 1997, Oswald et al., 2000). Alternatively, kriging is used to predict fuel levels to unsampled portions of the landscape (Balice et al., 2000b). However, each of these methods can be associated with high coefficients of variation (Yool et al., 2000). Previous attempts to evaluate fuels and wildfire hazards by using statistical analyses of topographic and spatial information have produced promising results (Balice 1990). The purpose of this poster is to present new analyses that will result in the construction of more robust databases of fuels characteristics. This is being done by utilizing combinations of topographic variables, geographic locations, and vegetation reflectance values that are more proximally related to fuel levels.



Ponderosa pine forest with a grass ground cover.

Methods

The area of interest is in higher elevations of the Los Alamos region where the fire hazards are known to be the greatest (Figure 1). Data were collected at 76 sites that had been selected through a random-stratified process (Figure 2). The field data include topographic information, soils characteristics, understory fuels and vegetation, and overstory canopy structures. In the office, the data were stored in computer databases and summarized (Balice et al., 1999; 2000b). Solar exposure functions were calculated and Kauth-Thomas transformations were performed (See sidebars). Then, lists of independent variables (Table 1) and dependent variables (Table 2) were compiled.

Correlation analyses and principal component analyses were conducted to identify collinearities among the independent variables. Then, the independent variables were normalized and used to create quadratic terms. Next, stepwise selection and backward elimination were used to prioritize regression models of the dependent variables and the normalized, first order and second order independent variables. Finally, one candidate model that optimized the suite of regression diagnostic statistics was retained for each of the dependent variables.

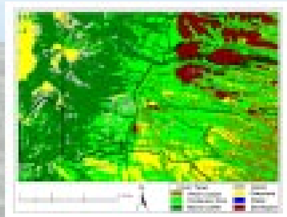


Figure 1. Portions of the Los Alamos region with high wildfire hazards.

Table 1. Independent variables

Slope (percent)
Exposure
Elevation (ft)
State Plane eastings (m)
State Plane northings (m)
Kauth-Thomas greenness index
Kauth-Thomas wetness index

Table 2. R-square values of selected models

Duff weight (t/ac)	0.0953
Litter weight (t/ac)	0.1097
Herbs, graminoids, and small shrubs (t/ac)	0.2955
Understory total fuels (t/ac)	0.3209
Understory fuels 1-hr to 100-hr (t/ac)	0.3656
Ground fuels and shrub-tree foliage (t/ac)	0.3644
Shrubs <10 ft tall (t/ac)	0.2838
Shrubs and trees <10 ft tall (t/ac)	0.2528
Trees <8 in. in diameter (trees/ac)	0.6513
Trees ≥8 in. in diameter (trees/ac)	0.3116
Overstory canopy coverage (percent)	0.5708

Kauth-Thomas Transformations

Spectral response patterns from spaceborne sensors are useful for characterizing forest vegetation. To assess the biophysical characteristics of the vegetation in the study region, two Kauth-Thomas (KT) linear transformations were applied to a Landsat Thematic Mapper (TM) image (July 3, 1997). The KT greenness index contrasts the near-infrared band (TM4) with the three visible TM bands (TM1, TM2, and TM3). Similarly, the KT wetness index contrasts the mid-infrared bands (TM5 and TM7) with the visible and near-infrared bands.

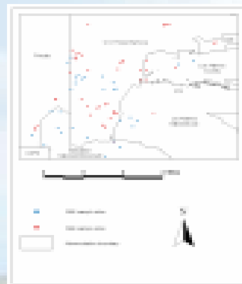


Figure 2. Location of sample sites in the Los Alamos region.

Results

For each of the dependent variables, the R-square values of the final curvilinear regression models are given in Table 2. The resulting models were suitable for prediction in all cases, except for duff and litter. Details of the modeling results for percent canopy cover are given in Table 3.

Table 3 Curvilinear Regression Model: Percent Canopy Cover

Source	df	SS	MS	F	Pr>F
Model	5	4596.7	919.3	16.23	0.0001
Error	61	3455.7	56.6		
Total	66	8052.4			

Model R-square = 0.571   Adjusted R-square = 0.536

Parameter Estimates

Variable	df	Estimate	St Err	T	Pr>|T|
Intercept	1	84.55	1.52	55.60	0.0001
State Plane N	1	3.91	0.97	4.05	0.0001
KT wetness^2	1	-3.13	1.01	-3.10	0.0030
KT wetness	1	-3.16	1.33	-2.37	0.0210
KT greenness^2	1	-1.48	0.66	-2.23	0.0297
Exposure^2	1	1.09	0.62	1.75	0.0856

Conclusions

Overstory and understory fuels can be predictively modeled using topographic, geographic and remotely sensed variables. These results can be used to develop more robust data layers for inputs to wildfire behavior models. They can also be used to develop more cost-effective mitigation action strategies and to increase public awareness. These and related results are being disseminated through the refereed literature (Miller et al., 2001, Yool et al., 2001).

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Mixed conifer forest with heavy ladder fuels.

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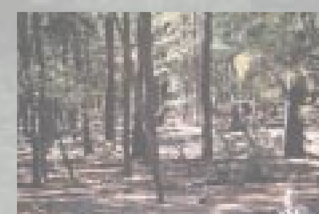
Aspen forest with a grass ground cover.

Solar Exposure Function

To partially assess the solar exposure that the forest vegetation receives during a growing season, the percent slope and slope aspect were entered into the following solar exposure function.

$$Exposure = slope \times \cos\left(\frac{\pi \times (aspect - 190)}{180}\right)$$

where *slope* is in percent and *aspect* is the slope aspect in degrees from true north. This unitless relationship assumes that a site on a relatively steep slope and with an aspect of 190° from true north receives the greatest solar input. The cosine term ranges from –1 for aspects of 10° to 1 for aspects of 190°.



Ponderosa pine forest with a pine-litter ground cover.

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